BASS, F. G.

Ю. В. [illegible]

Анализ [illegible]

II. СЕКЦИЯ РАСПРОСТРАНЕНИЯ РАДИОВОЛН

Руководитель [illegible]

[illegible]

(с 10 до 12 часов)

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(с 12 до 16 часов)

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О [illegible]

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К [illegible]

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К теории [illegible]

[illegible]

(с 18 до 22 часов)

А. [illegible],
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[illegible]

[illegible]

report submitted for the Centennial Meeting of the Scientific Technological Society of Radio Engineering and Electrical Communications im. A. S. Popov (VNORIE), Moscow, 8-12 June. 1959

9,9000 69948

AUTHORS: Kaner, E.A. and Bass, F.G. SOV/141-2-4-3/19

TITLE: Propagation of Electromagnetic Waves in a Medium With Random Irregularities Placed Above a Perfectly Conducting Plane

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, 1959, Vol 2, Nr 4, pp 553 - 564 (USSR)

ABSTRACT: Formulae are derived for the main statistical characteristics (average field, amplitude and phase fluctuations) and their dependence on the frequency and polarisation of radio waves and the distance and height of the receiving and transmitting aerials. In order to have a complete statistical description of the radiation field, it is necessary to know the distribution function f(δε) of the random deviations δε of the dielectric constant from the average value $\bar{\varepsilon}$ which for simplicity was taken as unity. However, at present the theory does not give an unambiguous answer to the problem of the distribution of δε . If one considers that this distribution is normal and takes only small fluctuations,

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then in order to obtain a complete statistical description it is sufficient to know only the second moment of $f(\delta\varepsilon)$ or the correlation function $\overline{\delta\varepsilon(\underline{r}_1)\delta\varepsilon(\underline{r}_2)}$. It is assumed that the correlation function is of the form given by Eq (1.1), where $\overline{\delta\varepsilon^2}$ is independent of the coordinates (statistically uniform medium) and the coefficient W depends only on the moduli of the differences between the components of the vectors $\underline{r}_1$ and $\underline{r}_2$. The distribution function of each of the components of the field $E = E_r + iE_i$ (E_r and E_i are the real and imaginary parts of E) is taken to be of the form given by Eq (1.2), where the symbols involved are defined by Eq (1.3). Using this formula, it is shown that away from the minima of the mean field, i.e. when $\overline{\zeta^2} \ll |\overline{E}|^2$, the mean phase is given by Eq (1.4). The

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mean square phase fluctuation is given by Eq (1.5), the mean amplitude by Eq (1.6), the mean square of amplitude fluctuation by Eq (1.7) and the mutual correlation between the amplitude and phase by Eq (1.8). Thus, a complete description of the radiation field is obtained if the mean field and the corresponding mean square values are known. In order to calculate these quantities, use is made of Maxwell's equations which, after the exclusion of the magnetic field, can be reduced to the form given by Eq (2.1). Assuming that $\varepsilon = 1 + \delta\varepsilon$, $\underline{E} = \bar{\underline{E}} + \zeta$, the final equations are of the form given by Eqs (2.3) and (2.4). These equations must be supplemented by the appropriate boundary conditions on the separation boundary. If the latter is a perfectly conducting plane, the tangential components of the field must be zero (Eq 2.5). The subscript "0" indicates that the quantities are evaluated at $z = 0$, where the z axis is normal to the separation boundary and passes

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through the point z_o at which the radiator is located. The x axis passes along the projection of the line connecting the point of observation $r(L,0,z)$ with the radiator $r_o(0,0,z)$. The boundary condition for the vertical component E_z is given by Eq (2.6). It is assumed that $|\nabla \delta \varepsilon| \ll k |\delta \varepsilon|$ or $k l \gg 1$, in which case polarization corrections can be neglected. Accordingly, the vector equations (2.3) and (2.4) can be reduced to the form given by Eqs (2.7) and (2.8), subject to the boundary condition given by Eq (2.9). The δ function on the right-hand side of Eq (2.7) is due to the presence of the source at the point $\underline{r}_o$. These equations are solved for the mean field in Section 3, and it is shown that in order to find this field above the perfectly conducting plane, it is sufficient to replace the propagation constant k by the quantity $\varkappa = k\sqrt{\varepsilon_{эфф}}$ in which

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$\varepsilon_{\vartheta\phi\phi}$ is given by Eq (3.11) (Which is the same as the value of $\varepsilon_{\vartheta\phi\phi}$ in an infinite medium - Ref 5). Section 4 is concerned with the statistical characteristics of the field in the distant zone. In this section, formulae are derived for the mean square fluctuations mentioned above. It is shown that the fluctuations increase rapidly near the minima of the mean field and this is associated with the interference structure of the electromagnetic field in space. The interference effects are most sharply defined when the amplitude of the direct and the reflected waves is the same. If the modulus of the amplitude reflection coefficient is different from unity, the interference phenomena do not lead to such a strong increase in the fluctuations. In the case of small reflection coefficients one can use the formulae obtained for an infinite medium. If the correlation function can be approximated by a formula of the form $\delta\varepsilon^2 \exp[-(x^2 + y^2)/l_{\parallel}^2 - z^2/l_{\perp}^2]$,

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the amplitude and phase fluctuations are given by Eq (4.17). The rapid increase in the relative fluctuations near interference minima and in the distant zone is not associated with an increase in the absolute fluctuations but a decrease in the regular component of the field. There are 7 references, of which 6 are Soviet and 1 is English.

ASSOCIATION: Institut radiofiziki i elektroniki AN USSR (Institute of Radiophysics and Electronics of the Ac.Sc., Ukrainian SSR)

SUBMITTED: March 19, 1959

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SOV/141-2-4-4/19

AUTHORS: Bass, F.G. and Kaner, E.A.

TITLE: Correlation of Electromagnetic Field Fluctuations in a Medium Having Random Irregularities and Placed Above a Perfectly Conducting Plane

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, 1959, Vol 2, Nr 4, pp 565 - 572 (USSR)

ABSTRACT: The present paper is the continuation of the paper on pp 553-564 of this issue. Using the results obtained in that paper, general formulae are derived for the spatial correlation functions for amplitude and phase fluctuations, assuming that the relative fluctuations are small. If the fluctuation part of the electromagnetic field is much smaller than the regular component (at points distant from the zeros of the latter) the phase and amplitude fluctuations are given by Eqs (1.1) and (1.2). The correlation between the amplitude and phase fluctuations at different points 1 and 2 is then given by Eqs (1.3) and (1.4). Under certain simplifying assumptions, it can be shown that the phase and amplitude correlations are equal and are given by Eq (1.5).

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Thus, the phase and amplitude correlation functions are completely defined by the quantity $\overline{\zeta_1 \zeta_2^*}$. Using Eq (1.6) derived in the previous paper, it can be shown that $\overline{\zeta_1 \zeta_2^*}$ is given by Eq (1.7). This equation is then used to calculate the correlation for two special cases, namely, the case of transverse and longitudinal correlation. There are 3 Soviet references.

ASSOCIATION: Institut radiofiziki i elektroniki AN USSR (Institute of Radiophysics and Electronics of the Ac.Sc. Ukrainian SSR)

SUBMITTED: March 19, 1959

Card 2/2

24.2400 69959

AUTHOR: Bass, F.G. SOV/141-2-4-14/19

TITLE: On the Theory of Artificially Anisotropic Dielectrics

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, 1959, Vol 2, Nr 4, pp 656 - 658 (USSR)

ABSTRACT: A number of recent works (Refs 1-4) consider the problem of the propagation of electromagnetic waves in a medium whose permittivity and permeability are periodic functions of one of the coordinates. In the following, an attempt is made to determine the average (over a period) electromagnetic field under the assumption that the deviations of the permittivity ε and permeability μ from their average values $\bar{\varepsilon}$ and $\bar{\mu}$ are small (the averaging being carried out over the space period). Further, it is assumed that ε and μ are real functions but otherwise they can be arbitrary, scalar or tensorial real periodic functions of the coordinates. The period is much smaller than the wavelength in the medium. The electric and magnetic fields E and H are given by:

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$$E = E_o + \zeta; \quad H = H_o + \eta;$$
$$\bar{E} = E_o; \quad \bar{H} = H_o. \qquad (1)$$

By averaging the Maxwell equations for E and H, it is possible to obtain the averages E_o, H_o, ζ and η. These are defined by:

$$\text{rot } E_o = \frac{i\omega}{c}(\overline{\mu}H_o + \overline{\beta\eta}); \quad \text{rot } H_o = -\frac{i\omega}{c}(\bar{\varepsilon}E_o + \overline{\alpha\zeta}); \qquad (2)$$

$$\text{rot } \zeta = \frac{\omega}{c}(\bar{\mu}\eta + \beta H_o); \quad \text{rot } \eta = -\frac{i\omega}{c}(\bar{\varepsilon}\zeta + \alpha E_o) \qquad (3)$$

where $\beta = \mu - \bar{\mu}$; $\alpha = \varepsilon - \bar{\varepsilon}$. The quantity α and β can be represented by the Fourier series given in Eqs (4). Consequently, ζ and η can be expressed by Eqs (5).

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The fields E_o and H_o are therefore given by Eqs (6), where the parameters μ' and ε' are defined by Eqs (7). The permittivity and permeability tensors are expressed by Eqs (8). The author thanks P.V. Bliokh and E.A. Kaner for valuable discussions. There are 6 Soviet references.

ASSOCIATION: Institut radiofiziki i elektroniki AN USSR (Institute of Radiophysics and Electronics of the Ac.Sc., Ukrainian SSR).

SUBMITTED: May 15, 1959

24.2400

80141

S/141/59/002/06/023/024
E032/E314

AUTHOR: Bass, F.G.

TITLE: Effective Dielectric-constant Tensor in a Medium With Random Irregularities

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, 1959, Vol 2, Nr 6, pp 1015 - 1016 (USSR)

ABSTRACT: The equations for the mean electric field $\bar{E}$ and the fluctuation part ξ were shown in Refs 1 and 2 to be of the form given by Eqs (1) and (2). If $\delta\varepsilon$ is small compared with the mean value $\bar{\varepsilon}$, Eqs (1) and (2) can be simplified to the form given by Eq (3), where W is the correlation coefficient between fluctuations in the dielectric constant, which is considered to be an even function. If the electric field varies much more slowly than the correlation coefficient, then Eq (3) can again be simplified into the form given by Eq (4), where the effective complex dielectric-constant tensor is given by Eq (5). The mean electric field in a medium with anisotropic irregularities can be described by the same equations as those used in the theory of crystals and,

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consequently, two phase velocities are possible (Ref 3). If the corresponding integrals are convergent, then in Eq (3) it is possible to expand the exponent in the expression under the integral sign into a series of powers of

$$k\sqrt{\varepsilon}\,\rho .$$

The expression for ε'_{ik} is then found to be given by Eq (6). If $\delta\varepsilon$ depends only on a single coordinate, say, x , then the correlation coefficient depends only on ρ_x ($\underline{\rho} = \underline{r} - \underline{r}'$) . If the integration in Eq (5) is completed with respect to ρ_y and ρ_z and the resulting expression is expanded in series of powers of

$$k\sqrt{\varepsilon}$$

then one obtains the relation given by Eq (7), where:

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$$l = \int_0^{\infty} W(\rho_x) d\rho_x \; ; \quad i \neq x \text{ or } k \neq x .$$

The expression for the effective dielectric-constant tensor, when the fluctuations $\delta\varepsilon$ depend on only one coordinate, can also be obtained without assuming that $\delta\varepsilon$ is small, provided terms of the order of $k^2\bar{\varepsilon}$ in Eq (2) can be neglected. If, further, one also neglects ζ_y and ζ_z, then the second equation of the system given by Eq (2) simplifies to the form given by Eq (8). If the averaging process is carried out for Eq (8), then since $\bar{\zeta}_x = 0$, one obtains Eq (9) and, hence, Eq (10).

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Effective Dielectric-constant Tensor in a Medium With Random Irregularities

There are 4 Soviet references.

ASSOCIATION: Institut radiofiziki i elektroniki AN USSR (Institute of Radiophysics and Electronics of the Ac.Sc., Ukrainian SSR)

SUBMITTED: September 21, 1959

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9 (9)

AUTHORS: Kaner, E. A., Bass, F. G., SOV/20-127-4-17/60

TITLE: On the Statistic Theory of the Propagation of Radio Waves Over an Ideally Conducting Plane

PERIODICAL: Doklady Akademii nauk SSSR, 1959, Vol 127, Nr 4, pp 792 - 795 (USSR)

ABSTRACT: In the present paper, the statistic characteristic electromagnetic field propagated in a medium with small random fluctuations $\delta\varepsilon$ of the dielectric constant $\varepsilon = \langle\varepsilon\rangle + \delta\varepsilon$ over an ideally conducting plane is calculated. It is assumed that the medium over the surface is statistically homogeneous, and that $\langle\varepsilon\rangle$ and $\langle\delta\varepsilon^2\rangle$ do not depend on time and on the coordinates. The problem is restricted to large-scale fluctuations, i.e. the correlation radius is large as compared with the wave length. For a complete statistic description of the field, the mean value of the field and the mean square of the fluctuation components must be found. In a limited medium, the fluctuations grow near the interference minimum of the field components. The theoretical results obtained in the consideration of the problem described are further dealt with. On the basis of the

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Maxwell equation and neglecting polarization corrections, the Maxwell equation is transformed into $\Delta\vec{E} + k^2(\vec{E} + \langle \xi\, \delta\varepsilon \rangle) = -p\delta(\vec{r}-\vec{r}_0)$, (2). This method of statistic description was developed in the papers by Lifshits and collaborators (Ref 2). A solution is found which shows that at a sufficiently large distance from the source the distribution of the components ξ is normal at any distribution law of $\delta\varepsilon$. In equation (2), $\vec{E}$ denotes the regular and ξ the fluctuation components, $k=\omega/c$, $\vec{p}=4\pi k^2\vec{d}$. At a distance $L \gg kl^2$ from the interference minimum, the distribution of the phase and amplitude is a Gaussian distribution, near the minimum it is a distribution according to the law by Rayleigh. The conditions obtained mean that for a complete statistic description of the electromagnetic field it is sufficient to find the mean (regular) field and the mean square value of the fluctuations $\xi_{\pm}(\vec{r})=k^2\int\limits_{z>0} d\vec{r}'\,\varphi_{\pm}(\vec{r};\vec{r}')E_{\pm}(\vec{r}')\delta\varepsilon(\vec{r}')$

for each field component. There are 3 references, 2 of which are Soviet.

ASSOCIATION: Institut radiofiziki i elektroniki Akademii nauk SSSR (Institute of Radiophysics and Electronics of the Academy of Sciences, USSR)

PRESENTED: April 8, 1959, by M. A. Leontovich, Academician

SUBMITTED: April 4, 1959

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S/141/60/003/01/007/020
E032/E414

AUTHOR: Bass, F.G.

TITLE: Boundary Conditions for the Average Electromagnetic Field on a Surface with Random Irregularities and Impedance Fluctuations

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, 1960, Vol 3, Nr 1, pp 72-78 (USSR)

ABSTRACT: The propagation of electromagnetic waves above a surface with random irregularities has been discussed by Feynberg (Ref 1) in the case of a vertical dipole placed on a certain average plane surface relative to which the random irregularities are assumed to take place. It was shown in Ref 1, that the propagation of the average electromagnetic wave above a surface with random irregularities is equivalent to the propagation above a plane surface having a certain effective complex dielectric constant which depends on the statistical characteristics of the random irregularities. The present paper gives a derivation of the boundary conditions for the average electromagnetic field over a

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surface (which is not necessarily plane) with random irregularities both in geometrical form and electrical properties. The discussion is limited to well-conducting surfaces which satisfy the Leontovich boundary conditions. The discussion begins with a consideration of the propagation of a sonic wave over a surface with a random impedance. The boundary condition for the field ψ on the surface can be written in the form given by Eq (1). The orthogonal system of coordinates employed is as follows: the Z axis directed along the normal to the underlying surface, and the X and Y axes are chosen so that they are tangential to the principle lines of curvature. In Eq (1), η is the impedance of the separation boundary, $k = \omega/c$, and the dependence on time is taken to be of the form $e^{-i\omega t}$. The random impedance may be looked upon as a sum of the average impedance and the random component, and similarly for the field ψ. If Eq (1) is statistically averaged, one

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is led to Eq (2) where the horizontal bar indicates average quantities. On subtracting Eq (2) from Eq (1), and neglecting second order quantities, Eq (3) is obtained. The boundary conditions for ψ can be found by expressing ψ' (the random component of the field) in terms of $\bar{\psi}$ using Eq (3) and then substituting into Eq (2). The resulting boundary condition is given by Eq (4) and it is clear from this equation that the boundary condition is non-local, ie the derivative on the left depends on the value of $\bar{\psi}$ on a certain area having a centre $\underline{r}$ and whose effective linear dimensions are of the order of the correlation radius between $\alpha(\underline{r})$ and $\alpha(\underline{r}')$. If the correlation radius is much smaller then the radius of curvature, V is the Green function for the plane. If one assumes that the correlation function depends only on the distance between the points $\underline{r}$ and $\underline{r}'$, the boundary conditions given by Eq (4) can be rewritten in the form given by Eq (5).

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The case is then discussed where the integral boundary

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condition goes over into a local one. The discussion is concluded with a consideration of the Leontovich boundary conditions. On a random surface $z = \zeta(x,y)$, these conditions are of the form given by Eq (9) where $\underline{E}$ and $\underline{H}$ are the total electric and magnetic fields and $\underline{E} = \overline{\underline{E}} + \underline{e}$, $\underline{H} = \overline{\underline{H}} + \underline{h}$. If the boundary conditions (9) are applied to the surface $z = 0$, and the appropriate averaging process is carried out, the average and fluctuating components of the electric field are given by Eq (10). It is assumed that impedance fluctuations are not correlated to geometrical fluctuations. In order to find e_z and the z derivative of $e_{x,y}$ use is made of Eq (11) which gives the field at an arbitrary point in the upper half-space in terms of the tangential components of the electric field on the surface (Ref 2), where $\underline{G}^{(i)}$ is the magnetic field due to a dipole whose moment is in the direction of the i-th axis, the tangential components of the electric

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field on the average surface being zero. If the integration surface is approximately plane, the expressions given by Eq (12) are obtained. If on the other hand impedance fluctuations can be neglected, and geometrical fluctuations are uniform, the expressions given by Eq (13) are obtained. The theory is then applied to the case of the propagation of electromagnetic waves due to a point source over a spherical earth. In conclusion the author thanks Ye.L.Feynberg for discussing the results and E.A.Kaner for helpful suggestions. There are 5 Soviet references.

ASSOCIATION: Institut radiofiziki i elektroniki AN USSR (Institute of Radiophysics and Electronics, AS UkrSSR)

SUBMITTED: July 23, 1959

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S/141/60/003/02/006/025
E192/E382

AUTHORS: Bass, F.G. and Khankina, S.I.

TITLE: On the Theory of the Propagation of Electromagnetic Waves in a Nonhomogeneous Medium with a Fluctuating Permittivity

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, 1960, Vol 3, Nr 2, pp 216 - 225 (USSR)

ABSTRACT: The electric field E in a medium with random nonhomogeneities satisfies the following equation:

$$\text{rot rot } E - k^2 \varepsilon E = 0 \quad (1.1)$$

where $k^2 = \omega^2/c^2$ (ω is the frequency and c is the velocity of light) and ε is the permittivity which can be represented as $\varepsilon = \bar{\varepsilon}(r) + \delta\varepsilon(r)$, where $\bar{\varepsilon}(r)$ is the average permittivity and $\delta\varepsilon(r)$ is the random permittivity component. The problem is solved under the assumption that the following inequalities are fulfilled:

$$\left|\overline{\delta\varepsilon^2}\right|^{1/2} / \left|\bar{\varepsilon}\right| \ll 1 ; \quad \lambda \ll \ell \ll a \ll L$$

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where λ is the wavelength,
ℓ is the correlation radius of the random permittivity component,
a is an interval of which $\bar{\varepsilon}(r)$ changes significantly,
L is the optical length of the route.

Eq (1.1) can be solved by the method of successive approximations, so that the field can be represented by Eq (1.2), where the principal and the first approximations can be determined from Eqs (1.3) and (1.4), respectively. In many cases, $\bar{\varepsilon}$ can be regarded as the function of z only. In this case, if the electric field of the first approximation is perpendicular to the axis z, it is given by Eq (2.1); if the field is inclined to the axis z it is expressed by Eqs (2.2). Eq (1.4) can be written as Eqs (2.3). The solution of the second of these equations takes the form of Eq (2.4). This satisfies Eq (2.5). The solution of Eq (2.5) is in the form of Eq (2.6). The

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following statistical characteristics of the random components of the electric field, as given by Eq (2.6), are of interest: the reflection coefficients $V_{1,2}$ and depolarisation coefficients $D_{1,2}$ which describe the rotation of the polarisation plane. These coefficients are defined by Eqs (2.7). Further parameters of interest are: the average square value of the phase fluctuation β_i and the relative amplitude fluctuations α_i and their correlation functions. These are defined by Eqs (2.8). The expressions for the reflection and depolarisation coefficients are in the form of Eqs (2.9), where K represents the correlation function for the permittivity fluctuations, while F_1 and F_2 are defined by Eqs (2.10). The correlation functions for the case of $L/k\ell^2 \ll 1$ are expressed by Eqs (2.11) and (2.12). The amplitude and phase fluctuations of the i-th component of the electric field can be expressed by Eq (3.2) (Refs 8,9).

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The ratio of the squared averages of the two quantities can be expressed by Eq (3.4). In the far region, the squared averages of the amplitude and phase fluctuations can be expressed by Eq (3.5). For the case of the near zone, these quantities can be expressed by Eqs (3.6). The attenuation of the mean field caused by the scattering due to the fluctuations can be determined from Eq (3.7), where G is the Green function. By solving this equation it is found that the attenuation function is given by:

$$\mu = \frac{1}{4} \frac{k^2}{\varepsilon(r)} \int_0^\infty K(r, \rho) d\rho \qquad (3.10) .$$

The authors express their gratitude to E.A. Kaner for discussing this work and N.G. Denisov for his interest in the work.

There are 12 references, 1 of which is English, 1 German and 10 are Soviet.

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On the Theory of the Propagation of Electromagnetic Waves in a Nonhomogeneous Medium with a Fluctuating Permittivity

ASSOCIATION: Khar'kovskiy institut radiofiziki i elektroniki AN USSR (Khar'kov Institute of Radiophysics and Electronics of the Ac.Sc. Ukrainian SSR)

SUBMITTED: July 11, 1959

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E192/E382

AUTHORS: Bass, F.G. and Khankina, S.I.

TITLE: Fluctuations of the Electric Field in a Gyrotropic Medium with Random Non-homogeneities Approximated on the Basis of Geometrical Optics

PERIODICAL: Izvestiya vysshikh uchenbykh zavedeniy, Radiofizika, 1960, Vol. 3, No. 3, pp 384 - 392

TEXT: The problem considered is of importance in the study of the ionosphere, the solar corona and certain other problems where the waves propagate in a plasma situated in a magnetic field. The electrical properties of such a medium can be described by the tensor expressed by Eqs (1), provided it is assumed that the magnetic field has the direction of the axis z . In these equations, ω_o is the plasma frequency, ω is the frequency of the electric field, N is the electron concentration in the plasma and H is the magnetic field. The electric field E in a gyrotropic medium is described by Eq. (2), where ε_{ik} are the components of the tensor as defined by Eqs. (1), while $k = \omega/c$. The solution of Eq. (2) is in the form

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Fluctuations of the Electric Field in a Gyrotropic Medium with Random Non-homogeneities Approximated on the Basis of Geometrical Optics

of Eq. (3), so that the expression for the function S(r) is in the form of Eq. (4). If the fluctuations of the tensor components are small in comparison with their average value, the fluctuation component can be determined by:

$$\delta\varepsilon_{ik} = \frac{\partial\varepsilon_{ik}}{\partial N}\partial N + \frac{\partial\varepsilon_{ik}}{\partial H}\delta H \qquad (5).$$

If it is assumed that the average values of the components are independent of the coordinates, the equation for S is:

$$S = kn\tau r + \sigma(r) \qquad (6),$$

where n is the refraction index,
τ is a unit vector having the direction of the wave propagation and
Card2/5 σ is the fluctuation of the phase.

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By substituting Eq. (6) into Eq. (4), the expression for σ is in the form of Eq. (7), whose various coefficients are defined by Eqs. (8); Θ is the angle between the direction of propagation and the magnetic field, $\delta\nu$ is the relative fluctuation of the concentration and δh is the relative fluctuation of the magnetic field. The refraction index is defined by Eq. (9). Eq. (7) can further be written as Eq. (7a), so that the expression for σ is given by Eq. (10). Now the fluctuation of the normal can be expressed by Eq. (11). Consequently, the average square of the phase fluctuations is expressed by Eq. (13), and the correlation function for the phase fluctuations at various points is defined by Eq. (14). The average square of the fluctuation of the normal is given by Eq. (15). When the direction of the propagation coincides with the direction of the magnetic field ($\Theta = 0$), Eqs. (13), (14) and (15) can be written as Eqs. (16), (17) and (18). In the case of $\Theta = \pi/2$, the average square of the phase, the correlation function and the average square of the fluctuation of

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the normal are expressed by Eqs. (19), (20) and (21) for the ordinary wave; in the case of the extraordinary wave, these parameters are given by Eqs. (22), (23) and (24). For the case of an extraordinary wave propagating at an arbitrary angle Θ in a strong magnetic field, the expressions for the above parameters take the form of Eqs. (25), (26) and (27). If the average value and the fluctuations of N and H depend on the coordinate z, the average square value of the phase fluctuation can be described by Eq (29). For $\Theta = 0$, this expression is in the form of Eq. (30). On the other hand, for $\Theta = \pi/2$ the phase fluctuation is described by Eq (31) for the ordinary wave and by Eq (32) for the extraordinary wave. There are 1 table and 3 Soviet references.

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S/141/60/003/03/004/014
E192/E382

Fluctuations of the Electric Field in a Gyrotropic Medium with Random Non-homogeneities Approximated on the Basis of Geometrical Optics

ASSOCIATION: Institut radiofizicheskiy i elektroniki AN USSR (Institute of Radiophysics and Electronics of the Ac.Sc., Ukrainian SSR)

SUBMITTED: November 27, 1959

Card 5/5

9.3100, 9.9000, 16.7800

77952
SOV/109-5-3-6/26

AUTHOR: Bass, F. G.

TITLE: Boundary Conditions for an Electromagnetic Field on a Surface With an Arbitrary Dielectric Permeability

PERIODICAL: Radiotekhnika i elektronika, 1960, Vol 5, Nr 3, pp 389-392 (USSR)

ABSTRACT: The boundary conditions of Leontovich greatly simplify theoretical analysis of wave propagation, but their application is limited to higher absolute values of dielectric permeability. A. D. Petrovskiy and Ye. L. Feynberg (this journal, 1960, Nr 3, p 385) proved the possibility of setting up a similar boundary condition for an arbitrary absolute value of dielectric permeability, assuming the field to be expressed by a plane wave, multiplied by a function of coordinates. This condition is not universal since it depends on the type of solution. This paper presents an exact boundary condition for

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the ele tric field component perpendicular to the separation plane between two media with dielectric permeabilities equal to 1 and ϵ, respectively, hereby assuming $|\epsilon| > 1$. The positive direction of the z-axis, which is perpendicular to the separation plane, is assumed from the 2nd medium with permeability ϵ towards the 1st plane having a permeability 1. The normal components in both media satisfy the equations

$$\Delta E_{1z} + \frac{\partial^2 E_{1z}}{\partial z^2} + k^2 E_{1z} = U, \quad (1)$$

$$\Delta E_{2z} + \frac{\partial^2 E_{2z}}{\partial z^2} + k^2 \epsilon E_{2z} = 0. \quad (2)$$

Notations are: Δ, two-dimensional Laplacian per coordinates x, y; $k = \omega/c$; U, source related by a certain relation to the current. On the boundary $z = 0$, E_{1z} and E_{2z} follow exact boundary conditions

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$$\frac{\partial E_{1z}}{\partial z} = \frac{\partial E_{2z}}{\partial z} \qquad E_{1t} = \varepsilon E_{2t} \tag{3}$$

Any function satisfying Eq. (2) can be expressed through its normal derivative on the boundary by the formula of Kirchoff, thus, function $\partial E_{2z}/\partial z$ also and

$$\frac{\partial E_{2z}}{\partial z}(\mathbf{r}) = \frac{1}{2\pi}\int\int_{-\infty}^{\infty}\frac{e^{ik\sqrt{\varepsilon}|\mathbf{r}'-\mathbf{r}|}}{|\mathbf{r}'-\mathbf{r}|}\frac{\partial^2 E_{2z}(\mathbf{r}')}{\partial z^2}\,dx'dy' \tag{4}$$

where r and r' are two-dimensional vectors with components x, y, and x', y'. Transforming this equation, substituting $\partial E_{2z}/\partial z$ by $\partial E_{1z}/\partial z$, and omitting index 1 for simplicity, Eq. (5) is derived

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$$\frac{\partial E_z(r)}{\partial z} = -\frac{1}{2\pi\varepsilon}\int\int_{-\infty}^{\infty}\frac{e^{ik\sqrt{\varepsilon}|r'-r|}}{|r'-r|}(k^2\varepsilon + \Delta_{r'})E_z(r')\,dx'dy' \quad \text{for } z = 0, \qquad (5)$$

which gives the final boundary condition sought. This condition is not local; i.e. the value $\partial E_z/\partial_z$ in point r is given by E_z within a certain area with linear dimensions $\lambda/|\sqrt{\epsilon}|$, because in Eq. (5) the exponent in the nucleus $\frac{e^{ik\sqrt{\epsilon}\rho}}{\rho}$ changes considerably within a distance of this order. For a good conductivity $\lambda/|\sqrt{\epsilon}|$ is of the order of the skin-thickness; but for a pure dielectric, of the order of the space-period of the nucleus oscillations. The exact boundary condition Eq. (5) is adapted to derivation of approximate conditions by introducing $\rho = r' - r$

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and new variables $E_z(r') - E_z(r+\rho)$ expanding $E_z(r+\rho)$ into series per powers of ρ, and taking into consideration that $\Delta'_r = \Delta_{r+\rho} = \Delta_r$. After changing to cylindrical coordinates and integration per ρ

$$\frac{\partial E_z(\mathbf{r})}{\partial z} = -\frac{ik}{\sqrt{\varepsilon}}\left(1+\frac{1}{k^2\varepsilon}\Delta_r\right)^{1/2} E_z(\mathbf{r}). \qquad (6)$$

The operator can be determined from

$$\left(1+\frac{1}{k^2\varepsilon}\Delta_r\right)^{1/2} = 1+\frac{1}{2}\frac{\Delta}{k^2\varepsilon}-\frac{1}{8}\left(\frac{\Delta}{k^2\varepsilon}\right)^2+\ldots$$
$$\ldots+\frac{\frac{1}{2}\left(\frac{1}{2}-1\right)\ldots\left(\frac{1}{2}-n+1\right)}{n!}\left(\frac{\Delta}{k^2\varepsilon}\right)^n+\ldots \qquad (7)$$

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The coefficients of series Eq. (7) decrease rapidly

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and, for practical purposes, two to three terms give satisfactory precision. The boundary condition in Eq. (6) becomes the Leontovich condition if only one term is taken in Eq. (7) which, of course, can be done only for $|\epsilon| \gg 1$. Another type of boundary condition is derived if the solution of Eq. (1) is sought in the form

$$E_z(r, z) = \int V(\varkappa, z)\, g_\varkappa(r)\, d\varkappa, \qquad (8)$$

where $g_\varkappa(r)$ is the complete orthonormal system of eigen-functions of the operator Δ. The integral in Eq. (8) designates summation per discrete spectrum and integration per continuous spectrum and integration per continuous spectrum ($\varkappa$ is vector number of the eigen-function). Subsituting Eq. (8) into Eq. (6) the last equation is expressed as

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$$\frac{\partial E_z}{\partial z} = -\frac{ik}{\sqrt{\varepsilon}}\int\left(1+\frac{\alpha(x)}{k^2\varepsilon}\right)^{1/2} V(x,\ 0)\, g_x(r)\,dx.$$

If E_z is a narrow wave package, so that it is possible to place in front of the integral, $\left(1+\frac{\alpha(x)}{k^2\varepsilon}\right)^{1/2}$, condition in Eq. (6) can be restated as

$$\frac{\partial E_z}{\partial z} = -\frac{i\kappa}{\sqrt{\varepsilon}}\left(1+\frac{\alpha(x_0)}{k^2\varepsilon}\right)^{1/2} E_z, \qquad (9)$$

$\alpha(K)$ is own number of operator Δ ; K_o corresponds to the center of gravity of the package. For the derivation of Eq. (9) it was assumed that

$$\frac{1}{2k^2|\varepsilon|}\left|\frac{d\alpha(x_0)}{dx}\right|\frac{\Delta x}{\left|\left(1+\frac{\alpha(x_0)}{k^2\varepsilon}\right)^{1/2}\right|} < 1, \qquad (10)$$

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where ΔK is width of wave package. For greater values of $|\epsilon|$ the limitations of ΔK are not important and we return to the conditions of Leontovich. Taking plane waves as eigen-functions of the operator Δ and the center of gravity of the wave package at k, then $a(k) \simeq -K^2$ and the boundary condition of Petrovskiy-Feynberg results in

$$\frac{\partial E_z}{\partial z} = -\frac{ik}{\sqrt{\epsilon}}\left(1-\frac{1}{\epsilon}\right)^{1/2} E_z, \qquad (11)$$

There are 2 Soviet references.

SUBMITTED: September 3, 1959

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25945
S/141/61/004/001/005/022
E033/E435

9.2100

AUTHOR: Bass, F.G.

TITLE: A contribution to the theory of combination scattering of waves on a rough surface

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, Vol.4, No.1, pp.58-66 1961

TEXT: The problem of the scattering of electromagnetic and sound waves on rough surfaces has been considered by R.Gans, A.A.Andronov and M.A.Leontevich but only for particular types of surface. The object of this article is the theoretical investigation of the scattering of such waves, without particularization of the nature of the surface irregularities, and to obtain a generalized expression for the intensity in a form applicable to any type of surface. The frequency spectrum is also investigated. It is shown that with scattering on a surface which changes with time, there occurs a combination scattering analogous to the Mandel'shtam-Raman effect. The general theory is applied to a number of concrete examples. Only surfaces which satisfy the following conditions are considered

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$$\left(\frac{\partial \zeta}{\partial x}\right)^2_{max}, \left(\frac{\partial \zeta}{\partial y}\right)^2_{max} \ll 1; \quad \frac{2\pi \zeta_{max}}{\lambda} \ll 1$$

where $z = \zeta(x,y)$ is the form of the scattering surface, λ is the wavelength of the incident radiation, i.e. the heights and declivities of the irregularities are small compared to the wavelength. It is also assumed that the frequency of the change of the surface is low compared to the frequency of the incident wave. These assumptions permit the use of quasi-statistical approximation. By using Maxwell's equations, an expression is obtained for the electric field in the semi-space above a plane surface separating two media which possess different complex dielectric permittivities. The analogous sound-wave case is also considered. The results are applied to a rough surface by considering the electric and magnetic field strengths in the two semi-spaces to be made up of components due to a plane surface and due to irregularities. Assuming that the surface $\zeta(x,y,t)$ is a homogeneous and stationary random function of the coordinates and time, then the frequency spectrum is determined by the Fourier transform from the time correlation function of the fields. The method is applied to radiation scattered by gravitational-capillary waves on the surface of a heavy incompressible liquid. In this case, the spectrum of the scattered radiation has two frequencies, which are disposed symmetrically with respect to the incident radiation and displaced by the same amount. Such a spectrum is typical of combination scatter. The case when the form of the surface satisfies the equation

$$\hat{L}\left(\frac{\partial}{\partial t}, \nabla_{\perp}\right)\zeta(\underline{r}, t) = 0 \qquad (35)$$

is next considered. $\hat{L}$ is an arbitrary function of its arguments, independent of $\underline{r}$ and t. The spectrum consists of l harmonics with frequencies $\omega + \Omega_l$, where Ω_l are the roots of the dispersion equations. The following examples are considered: 1) scatter of waves on fluctuations in a liquid in a basin of finite depth; 2) scatter on flexing waves of a thin plate; 3) scatter on a vibrating membrane. E.A.Kaner collaborated in

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this work. There are 9 references: 8 Soviet-bloc and 1 non-Soviet-bloc. The reference to an English language publication reads as follows: R.Gans, Ann.Phys., 79, 204 (1926).

ASSOCIATION: Khar'kovskiy institut radiofiziki i elektroniki AN UkrSSR (Khar'kov Institute of Radiophysics and Electronics, AS UkrSSR)

SUBMITTED: July 2, 1960

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87576

9.9000
9.9840

S/053/61/073/001/003/004
B006/B056

AUTHORS: Bass, F. G., Braude, S. Ya., Kaner, E. A., Men', A. V.

TITLE: Fluctuations of Electromagnetic Waves in the Troposphere in the Presence of a Boundary Surface

PERIODICAL: Uspekhi fizicheskikh nauk, 1961, Vol. 73, No. 1, pp. 89-119

TEXT: The present article is a review of theoretical and experimental studies on frequency, phase, and amplitude fluctuations of electromagnetic waves propagating in the troposphere as a result of atmospheric inhomogeneities. The effect of these fluctuations upon wave propagation in an infinite medium was first pointed out by Smolukhovskiy; further investigations by Einstein, Rayleigh and others (Refs. 1 - 14) followed. However, it proved to be of essential importance to the theory of wave propagation to take the existence of a boundary surface (surface of the Earth) into account; this leads to interference effects and other phenomena, and the theory is found to deviate essentially from the theory of fluctuation effects in a free atmosphere. The first part is a review of essential theoretical papers in this field. First, the statistical characteristics

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of the electromagnetic field above the plane boundary are discussed, after which fluctuations of the electromagnetic field in an infinite space are discussed. In the following, the qualitative effect of a boundary upon the fluctuations of this field are studied, and a mathematical representation of the fluctuation field and of the mean field above the boundary is discussed along with some limiting cases. In the following chapters, amplitude and phase fluctuations in the far zone are discussed, and the correlation of fluctuations above the boundary are dealt with. The second part presents results obtained by experimental investigations of fluctuations. In the course of investigations of ultrasonic wave propagation, frequently the presence of intensive fluctuations of radio-signals during their passage through the troposphere was observed. The investigations of these fluctuations, however, are mostly of local character, so that a comparison with the theory presents difficulties. In recent times, investigations have been extended over larger areas (above all oceans), so that more general results are now available. In detail, the authors discuss the method of measuring radiosignal fluctuations, the main characteristics of fluctuations, the various types of phase fluctua-

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tions, and the dependence of fluctuations on distance and meteorological conditions. An experimental-theoretical comparison proves the considerable influence exerted by taking the boundary into account: It leads to a quicker increase of fluctuations with growing distance, to a change in the frequency dependence, to the occurrence of fluctuation flashes, to a quick increase of the fluctuation intensity in the minima of the mean field, etc. The problems to be theoretically solved in future consist in taking the curvature of the boundary, the anisotropy, and the instability with time of the medium into account. B. A. Vvedenskiy is mentioned. There are 12 figures and 45 references: 29 Soviet and 16 US.

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S/141/61/004/002/017/017
E133/E135

9,9300

AUTHORS: Bass, F.G., and Kaner, E.A.

TITLE: Phase and amplitude fluctuations in very long distance propagation of electromagnetic waves above the earth's surface

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, 1961, Vol.4, No.2, pp. 377-379

TEXT: The authors consider the case when the receiver is below the transmitter's horizon. The intensity of the signal received then depends on scattering in the relatively small region of space where the directional diagrams of the transmitter and receiver intersect (see Fig.1). The present note is restricted to a consideration of the amplitude and phase fluctuations when these are determined by scattering, although the mean value of the field is determined by diffraction, i.e.:

$$\mathcal{E}(r) = (k^2/4\pi)^2 \; p \, [n' \, [en']] \int d\rho \; \delta\varepsilon(\rho) \; \exp(iq\rho)(rr_o)^{-1} \exp \; \exp(ikr + ikr_o) \qquad (1)$$

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An expression for the fluctuating component has been given by L.D. Landau and Ye.M. Lifshits (Ref.5: Elektrodinamika sploshnykh sred, "Electrodynamics of continuous media", GITTL, M., 1958). It can be found from this that the mean square values of the real, ξ_r, and imaginary, ξ_i, parts of the vector ξ, representing the fluctuations, are given by:

$$\langle \xi_i^2 \rangle = \langle \xi_r^2 \rangle = \frac{1}{2} \langle |\xi^2| \rangle \quad ; \quad \langle \xi_r \xi_i \rangle = 0 \qquad (2)$$

Eq.(2) holds for $(q\,\rho_0)^{-1} \ll 1$ (where ρ_0 is a characteristic dimension of the scattering volume and q represents the change in the wave vector due to scattering). This is true for the present situation. As the transmitter-receiver distance is increased, the fluctuating component falls off much less rapidly than the regular component. Hence at great distances the latter can be ignored in comparison with the former. At such distances the mean square fluctuations of phase and amplitude are given by:

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$$\langle \delta\varphi^2 \rangle = \pi^2/3, \quad \langle (\ln A - \langle \ln A \rangle)^2 = \pi^2/24,$$
$$\langle \varphi \rangle = \pi/2, \quad -\frac{\pi}{2} < \varphi < \frac{3\pi}{2} \qquad (6)$$

If the fluctuating component is small in comparison with the regular component, the fluctuations in phase and relative amplitude are equal and given by:

$$\sigma = \langle |\xi^2| \rangle / 2|E^2| = \frac{1}{2}(k^2 R \sin \chi / 4\pi (V|g_1 g_2)^2 \int \langle \delta\varepsilon^2 \rangle (r_o r)^{-1} \ldots$$
$$\ldots \quad dv\, W(q) \qquad (3)$$

This relation does not give explicitly the dependence on distance, frequency, etc. which can be derived, however, from:

$$\sigma \sim R^{-2(n+1)} (g_1 g_2)^{-2} \; |f(h_o)\; f\; (h)|^{-1} \exp\, (2t_i x) \qquad (8)$$

where: $x = (ka/2)^{1/3}\Theta$; $t_i \simeq 2.03$; and the remaining factors are shown in Fig.1.

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Reflection from the earth's surface is not considered in the present paper - the result of including it is simply to change slightly the effective scattering volume. Since the mean field value dies away exponentially, the fluctuations, in comparison, grow rapidly. It should be noted, however, that they also depend on the factor $R^{-2(n+1)}$ where, according to the experimental data (Ref.6: D.I. Vysokovskiy, book "Some Problems of Long Distance Propagation of Ultrashort Waves" (Nekotoryye voprosy dal'nego rasprostraneniya ul'trakorotkikh voli), Izd. AN SSSR, M., 1958), $n \simeq 2$. Eq.(8) was derived under the condition of small fluctuations: these do not, therefore, tend to infinity as the equation otherwise implies. The authors thank A.V. Men' for his opinion of the manuscript.
There are 1 figure and 6 Soviet references.

ASSOCIATION: Institut radiofiziki i elektroniki, AN USSR (Institute of Radiophysics and Electronics, AS Ukr.SSR)

SUBMITTED: October 21, 1960

30757
S/141/61/004/003/008/020
E192/E382

9,9645 (1538)

AUTHOR: Bass, F.G.

TITLE: Fluctuations of the parameters of an electromagnetic field propagating in a magnetically-active plasma having a randomly-varying electron concentration and magnetic field

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, v. 4, no. 3, 1961, 465 - 475

TEXT: The problem of the fluctuations of an electromagnetic field in a magnetically-active medium was studied in Ref. 1 - F.G. Bass and S.I. Khankina - this journal, 3, 384, 1960 - and Ref. 2 - N.G. Denisov, this journal, 3, 619, 1960, but it appears that the generalization of the results obtained in those works is of some interest. This is done in the following by using the perturbation method. The statistical characteristics of an electromagnetic field which passes through a magneto-active plasma are calculated; the fluctuations of the electron concentration and the external magnetic field as well as the field reflected from the layer of plasma are determined.

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Fluctuations of the parameters of E192/E382

The equations describing the propagation of electromagnetic waves in a magnetically active plasma are:

$$\mathrm{rot}\ \underline{H} = -\frac{i\omega}{c}\underline{E} + \frac{4\pi}{c} eN\underline{w};$$

$$\mathrm{rot}\ \underline{E} = \frac{i\omega}{c}\underline{H} \qquad (1)$$

$$-i\omega\underline{w} = \frac{e}{m}\underline{E} + \frac{e}{mc}\left[\underline{w}\underline{H}_0\right]$$

where $\underline{E}$ and $\underline{H}$ are alternating electric and magnetic fields, c is the velocity of light in vacuum, e is the electron charge, N is the electron concentration in the magnetically active plasma, $\underline{H}_0$ is the external magnetic field and $\underline{w}$ is the velocity of the electrons. It is assumed that

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all the quantities are sinusoidal functions of time. Each of the quantities in Eqs. (1) can be represented as a sum of its mean value and its fluctuation:

$$\underline{E} = \bar{\underline{E}} + \zeta; \quad \underline{H} = \bar{\underline{H}} + \underline{\tau}; \quad \underline{H}_o = \bar{\underline{H}}_o + \underline{h}; \quad N = N + \mu \qquad (2)$$

where the horizontal line above the symbol signifies statistical averaging. It is assumed that the fluctuations are small so that, by using the perturbation method, the fluctuation component of the electric field of Eqs. (1) is described by an equation of the type:

$$\left(\frac{\partial^2}{\partial x_i \partial x_k} - \delta_{ik}\Delta - k^2 \varepsilon_{ik} \right) \zeta_k = j_i \qquad (3)$$

where $\underline{j}$ is a vector. The propagation of the non-perturbed electromagnetic field is in the direction of the axis Oz and the plane Ozy coincides with $\underline{H}_o$. In this coordinate system the tensor ε_{ik} of the gyrotropic medium is expressed by:

$$\varepsilon_{xx} = 1 - \frac{v}{1 - u}; \quad \varepsilon_{xy} = -\varepsilon_{yx} = -\frac{iu^{1/2} v \cos \alpha}{1 - u};$$

$$\varepsilon_{yy} = 1 - \frac{v(1 - u \sin^2 \alpha)}{1 - u}; \quad \varepsilon_{yz} = \varepsilon_{zy} = \frac{uv \cos \alpha \sin \alpha}{1 - u};$$

$$\varepsilon_{zz} = 1 - \frac{v(1 - u \cos^2 \alpha)}{1 - u} \qquad (5)$$

where α is the angle between $\underline{H}_o$ and the axis Oz .

The solution of Eqs. (3) is assumed to be in the form of the Fourier integral of the coordinates x, y :

$$\underline{\zeta}(\underline{r}) = \int e^{i(\varkappa_x x + \varkappa_y y)} \underline{\zeta}(\underline{\varkappa}, z) d\underline{\varkappa}; \quad \underline{j}(\underline{r}) = \int e^{i(\varkappa_x x + \varkappa_y y)} \underline{g}(\underline{\varkappa}, z) d\underline{\varkappa} \quad (6) .$$

If the thickness of the layer where the fluctuations occur is L and the layer is perpendicular to the axis z , the expressions for the components ζ_j for the plane z = L are given by:

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$$\xi_x(L) = \frac{i}{2q_{10}(q_{10}^2 - q_{20}^2)} \int_0^L e^{iq_1(L-z)} \left[(a_1 - q_{10}^2) f_1(z) - a_2 f_2(z) \right] dz +$$

$$+\frac{i}{2q_{20}\left(q_{20}^2-q_{10}^2\right)}\int_0^L e^{iq_2(L-z)}\left[\left(a_3-q_{20}^2\right)f_1(z)-a_2f_2(z)\right]dz;$$

$$\xi_y(L)=\frac{i}{2q_{10}\left(q_{10}^2-q_{20}^2\right)}\int_0^L e^{iq_1(L-z)}\left[a_2f_1(z)+\left(a_1-q_{10}^2\right)f_2(z)\right]dz+$$

$$+\frac{i}{2q_{20}\left(q_{20}^2-q_{10}^2\right)}\int_0^L e^{iq_2(L-z)}\left[a_2f_1(z)+\left(a_1-q_{20}^2\right)f_2(z)\right]dz; \quad (8)$$

$$\xi_z(L)\simeq-\frac{\varepsilon_{zx}}{\varepsilon_{zz}}\xi_x(L)-\frac{\varepsilon_{zy}}{\varepsilon_{zz}}\xi_y(L).$$

where the various functions are defined by:

$$f_1(z) = -g_x(z) + \frac{\varepsilon_{xz}}{\varepsilon_{zz}} g_z(z); \quad f_2(z) = -g_y(z) + \frac{\varepsilon_{yz}}{\varepsilon_{zz}} g_z(z);$$

$$a_1 = k^2\left(\varepsilon_{xx} + \frac{\varepsilon_{xz}^2}{\varepsilon_{zz}}\right); \quad a_2 = k^2\left(\varepsilon_{xy} - \frac{\varepsilon_{xz}\varepsilon_{yz}}{\varepsilon_{zz}}\right);$$

$$a_3 = k^2\left(\varepsilon_{yy} - \frac{\varepsilon_{zy}^2}{\varepsilon_{zz}}\right).$$

In the above the index i can assume the value of 1, which corresponds to an ordinary wave or a value of 2 corresponding to the extraordinary wave. Eqs. (8) are derived under the assumption that $\lambda/2\pi = 1/k \ll \ell \ll L$ m where ℓ denotes the characteristic dimensions of the random irregularities in the electron concentration and the magnetic field. The above results can be used to investigate the fluctuations of the phase, incidence angles and relative and absolute fluctuations of the electromagnetic fields passing through the layer; it is also possible to determine the absolute fluctuations of the electromagnetic field reflected from the layer. The phase fluctuations $\delta\varphi$ and the relative amplitude fluctuations δA are defined by the following formulae (Ref. 3 - E.A. Kaner, F.G. Bass, this journal, 2, 553, 1959):

$$\delta\varphi = \mathrm{Im}(\zeta/\bar{E}); \quad \delta A = \mathrm{Re}(\zeta/\bar{E}) \tag{9}$$

The correlation functions of these quantities at points r_1 and r_2 are written as:

$$K(r_3, r_2) = \overline{\delta\varphi(\underline{r}_1)\delta\varphi(\underline{r}_2)}, \quad P(\underline{r}_1, \underline{r}_2) = \overline{\delta A(\underline{r}_1)\delta A(\underline{r}_2)} \tag{10}$$

In using Eqs. (8) and (6) for determining the effect of the fluctuations of the electron concentration and the magnetic field it is assumed that the propagating field is in the form of normal plane waves.

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Fluctuations of the parameters ....

The components $\overline{\zeta_j^2}$ and the phase and amplitude correlation functions are determined for the following special cases:

1) $\alpha = \pi/2$ for the ordinary wave;
2) $\alpha = \pi/2$ for the extraordinary wave;
3) $\alpha = 0$;
4) $u \gg 1$, which corresponds to strong magnetic fields.

The attenuation coefficient of the mean field is also determined. It is also shown that if ε_{ik} is a slowly-changing function of the three coordinates x, y, z, the mean square value of the fluctuations of the phase is equal to the average square value of the amplitude fluctuations and is half the value of the average square phase fluctuation in the far zone. This effect is demonstrated in a manner similar to that presented in Ref. 4 (F.G. Bass, S.I. Khankina, this journal, 3, 216, 1960). There are 6 Soviet references.
Acknowledgments are expressed to S.I. Khankina.

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S/141/61/004/003/008/020
Fluctuations of the parameters ... E192/E382

ASSOCIATION: Institut radiofiziki i elektroniki AN UkrSSR (Institute of Radiophysics and Electronics of the AS UkrSSR)

SUBMITTED: January 21, 1961

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30758
S/141/61/004/003/009/020
E032/E114

9,9000 (1036)

AUTHOR: Bass, F.G.

TITLE: Propagation of Radio waves over a statistically irregular surface

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, 1961, Vol.4, No.3, pp. 476-483

TEXT: In a previous paper (Ref.1: Izv. vyssh. uch. zav. Radiofizika, Vol.3, 72 (1960)) the present author derived a boundary condition for the average electromagnetic field on a surface with random irregularities. If it is assumed that the random irregularities are statistically uniform, i.e. the correlation function for the height of the surface at points r and r' is a function of $\rho = r - r'$ only, then the boundary conditions on the surface $z = 0$ are of the form:

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$$E_{x,y} = \mp \xi H_{y,x} + \frac{\overline{\zeta^2}}{2\pi} \int ds \left\{ v(\varrho) \left[\Delta_\varrho \frac{\partial W(\varrho)}{\partial \varrho_{x,y}} E_z - \right.\right.$$

$$\left. - \nabla_{r'} E_z \nabla_\varrho \frac{\partial W(\varrho)}{\partial \varrho_{x,y}} + \frac{\partial \nabla r' E_\perp}{\partial z} \frac{\partial W(\varrho)}{\partial \varrho_{x,y}} - \frac{\partial E_\perp}{\partial z} \nabla_\varrho \frac{\partial W(\varrho)}{\partial \varrho_{x,y}} \right] + \quad (1)$$

$$\left.\left. + v''(\varrho) \left[E_z \frac{\partial W(\varrho)}{\partial \varrho_{x,y}} - \frac{\partial E_{x,y}}{\partial z} W(\varrho) \right] \right\}$$

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Here E and H are the average electric and magnetic fields, ξ is the average impedance and $\overline{\zeta^2}$ is the average square of the surface irregularity, W is the correlation coefficient between the irregularities at two different points,

$$v(\varrho) = \frac{e^{ik\varrho}}{\varrho}, \quad v''(\varrho) = \lim_{z \to 0} \frac{\partial^2}{\partial z^2} \frac{e^{ik\sqrt{\varrho^2 + z^2}}}{\sqrt{\varrho^2 + z^2}} .$$

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and E and H are functions of r'. The integration in Eq.(1) is with respect to r'. The first case investigated in the present paper is that where the irregularities are both uniform and isotropic, i.e. the case where W depends only on the distance between the points r and r' only. The plane of incidence is chosen to lie in the xz plane and the boundary condition (1) under these assumptions splits into two independent boundary conditions: one for the vertical and one for the horizontal polarisations. The reflection coefficient is then determined for the vertical polarisation (it is defined as the ratio of the reflected magnetic field to the incident magnetic field), while for the horizontal polarisation it is defined as the ratio of the reflected electric field to the incident electric field. Maxwell's equations are then used to express the electric field in terms of the magnetic field in the case of the vertical polarisation, and the magnetic field in terms of the electric field in the case of the horizontal polarisation. The solution of Maxwell's equations is then sought in the form

$$H_y = (e^{-ik_z z} + R_B e^{-ik_z z}) H_{0y} e^{ik_x x}$$

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(vertical polarisation; $H_x = H_z = 0$);
and

$$E_y = (e^{-ik_z z} + R_r e^{ik_z z}) \times E_{0y} e^{ik_x x}$$

(horizontal polarisation; $E_x = E_z = 0$).
Substitution of these solutions into Eq.(1) and integration with respect to the angles are shown to lead to closed formulae for the reflection coefficients. For glancing incidence the reflection coefficients are shown to be given by:

$$R_s = \left\{1 - \frac{1}{\cos\theta}\left[\xi + \frac{\overline{\zeta}^2 \sqrt{kl}\, e^{i\frac{3\pi}{4}}}{2\sqrt{2\pi}\, l^2}\int\limits_0^\infty x^{-3/2}\frac{dW}{dx}dx\right]\right\} \times \qquad (\ldots$$

$$\times \left\{1 + \frac{1}{\cos\theta}\left[\xi + \frac{\overline{\zeta}^2 \sqrt{kl}\, e^{i\frac{3\pi}{4}}}{2\sqrt{2\pi}\, l^2}\int\limits_0^\infty x^{-3/2}\frac{dW}{dx}dx\right]\right\}^{-1};$$

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(vertical polarization)
and

$$R_r = -1 + 2\left[\xi - \frac{2e^{\frac{i\pi}{4}} k \overline{\zeta^2}}{\sqrt{2\pi k l}} \int_0^{\infty} x^{-1/2} \frac{dW}{dx} dx\right] \cos\theta. \qquad (9)$$

(horizontal polarization).
In these equations ℓ is a characteristic linear dimension of the irregularities. A formula similar to Eq. (8) is said to have been derived by S.Ya. Braude (Ref. 2: Izv.vuz.Radiofizika, v.2, 691, 1959). However, Braude did not point out that the formula would only hold provided the angle of incidence satisfied the condition

$$\pi/2 - \theta \ll \sqrt{2/k\ell}\ .$$

The knowledge of the reflection coefficients for plane waves can be used to obtain the reflected field for a wave of arbitrary configuration using the method put forward by L.M. Brekhovskikh (Ref. 3: "Wave propagation in random media", Izd. AN SSSR, Moscow, 1957). As an example of this general problem the author

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considers the propagation of electromagnetic waves emitted by a vertical dipole placed above a random surface. The Hertz vector then has only one component which is parallel to the dipole axis. It consists of two parts, namely, the reflected part and the incident part and these are given by:

$$\Pi_{пад} = \frac{e^{ikR}}{R}; \quad \Pi_{отр} = \frac{ik}{2} \int_{\pi/2+i\infty}^{\pi/2-i\infty} H_0^{(1)}(kr\sin\theta)\, e^{ik(z+z_0)\cos\theta} R_в(\theta) \sin\theta d\theta. \tag{13}$$

In these equations $\Pi_{пад}$ is the incident-wave component, $\Pi_{отр}$ is the reflected-wave component and R is the distance from the dipole to the point of observation. Moreover, r is the distance from the projection of the dipole onto the plane z = 0 to the projection of the point of observation onto this plane; z_0 and z are the heights of the dipole and of the point of observation above the plane z = 0 and $H_0^{(1)}$ is the zero-order

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Hankel function of the first kind. If the condition

$$k(z + z_o) \gg \left|(\xi_{eff} + F(\Theta)\right|^{-1}_{min}$$

is satisfied, then

$$\Pi_{отр} = \frac{e^{ikR_1}}{R_1}\left\{R_B(\Theta_o) - \frac{i}{2kR_1}\left[R_B''(\Theta_o) + R_B'(\Theta_o)\,ctg\,\Theta_o\right]\right\} \quad (14)$$

where R_1 is the distance from the point of specular reflection of the dipole to the point of observation, Θ_o is the specular reflection angle, R_B is the reflection coefficient (see above), and primes above symbols represent differentiation with respect to Θ_o. In addition to the above waves, surface waves can also be propagated over random surfaces. These waves play an important part in modern electronics since they are known to interact with electron beams (L.A. Vaynshteyn, Ref.5: Elektromagnitnyye volny, "Electromagnetic Waves", Izd. Sov. radio, M., 1957). It is shown that if $k\ell \ll 1$, then in the case of a perfectly conducting plane with random irregularities, there is a surface wave which

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is propagated with a velocity $v < c$ and is not damped along the x axis. When $k\ell \gg 1$ the surface wave is attenuated both along the z and the x axes. The next section is concerned with the propagation of scalar waves over random surfaces. The particular case investigated is that where the scalar field vanishes on the irregular surface. It is shown that the boundary condition now becomes

$$\bar{\psi} = -\frac{\overline{\zeta^2}}{2\pi} \int V''(\rho)\, W(\rho)\, \frac{\partial \bar{\psi}}{\partial z}\, dS \tag{26}$$

and the reflection coefficient is given by

$$R_c = -1 + 2k\overline{\zeta^2} \left\{ k - i \int_0^{\infty} \frac{e^{ik\rho}}{\rho} \frac{d}{d\rho} \left[W(\rho)\, J_o(k_x \rho) \right] d\rho \right\} \tag{27}$$

The final section is concerned with general irregular surfaces where the irregularities are functions of one coordinate only. In the case of a quasi plane wave and glancing propagation, the boundary condition was shown to be, in Ref.1,

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$$E_x = -\eta_{eff}^{(x)} H_y, \qquad E_y = \eta_{eff}^{(y)} H_x \tag{31}$$

where η_{eff} is the effective impedance.
Using Maxwell's equations, one obtains the following boundary condition for E_z:

$$\frac{\partial E_z}{z} = -ik \left[\eta_{eff}^{(x)} \cos^2\varphi + \eta_{eff}^{(y)} \sin^2\varphi\right] E_z \tag{32}$$

where φ is the angle between the direction of propagation and the x axis.
There are 5 Soviet references.

ASSOCIATION: Institut radiofiziki i elektroniki, AN USSR (Institute of Radiophysics and Electronics, AS Ukr.SSR)

SUBMITTED: April 29, 1960

Card 9/9

22904
S/109/61/006/004/019/025
E032/E314

9,9000

AUTHOR: Bass, F.G.

TITLE: On the Electrodynamic Boundary Conditions on a Plane Surface with an Arbitrary Value of the Dielectric Constant

PERIODICAL: Radiotekhnika i elektronika, 1961, Vol. 6, No. 4, pp. 655 - 656

TEXT: In a previous paper (Ref. 1) the present author derived the boundary condition for the normal component of the electric field on a plane surface with an arbitrary value of the dielectric constant. In many cases, this boundary condition does not represent the complete solution of the problem. For example, in the case of fields for which the normal component is identically zero, this boundary condition becomes an identity and the boundary problem should be solved using the boundary conditions for the tangential components. The boundary conditions for the tangential components of the electric field can be obtained from the Green formula and the exact boundary conditions using the method analogous to that employed in Ref. 1. These boundary conditions are of the form

$$[\vec{n}, \vec{E}(\vec{r})] = -\frac{ik}{2\pi}\int \frac{e^{ik\sqrt{\varepsilon}|\vec{r}-\vec{r}'|}}{|\vec{r}-\vec{r}'|}\left\{[\vec{n}[\vec{n}, \vec{H}(\vec{r}')]] + \frac{1}{k^2\varepsilon}[\vec{n}\nabla](\nabla[\vec{n}, \vec{H}(\vec{r}')])\right\} d\vec{r}' \quad \text{при (WHEN) } z = 0. \qquad (1)$$

In this expression $\vec{E}$ and $\vec{H}$ are the electric and magnetic fields,

$k = \omega/c$,

ε is the complex dielectric constant and

$\vec{n}$ is the outward normal to the plane $z = 0$.

If $|\varepsilon| \gg 1$ then Eq. (1) can be rewritten in the form

$$[\vec{n}, \vec{E}] = \frac{1}{\sqrt{\varepsilon}}\left(1 + \frac{1}{k^2\varepsilon}\Delta\right)^{-1/2}\left([\vec{n}[\vec{n}, \vec{H}]] + \frac{1}{k^2\varepsilon}[\vec{n}\nabla](\nabla[\vec{n}, \vec{H}])\right) \quad \text{при (WHEN) } z = 0. \qquad (2)$$

where Δ is the two-dimensional Laplace operator. The magnetic field can be excluded from Eq. (2) with the aid of the Maxwell equations. After some rearrangement the boundary conditions for the electric field become

$$\text{WHEN (при) } z = 0: \quad \frac{\partial E_{x,y}}{\partial z} + ik\sqrt{\varepsilon}\left(1 + \frac{1}{k^2\varepsilon}\Delta\right)^{1/2} E_{x,y} = \frac{\varepsilon - 1}{\varepsilon}\frac{\partial E_z}{\partial x,y}, \quad \frac{\partial E_z}{\partial z} = -\frac{ik}{\sqrt{\varepsilon}}\left(1 + \frac{1}{k^2\varepsilon}\Delta\right)^{1/2} E_z. \tag{3}$$

On expanding the boundary condition given by Eq. (2) in powers of $\Delta/k^2\varepsilon$ and retaining the first term only, the Leontovich condition is obtained. The boundary condition given by Eqs. (3) are then used to solve the following problem. Consider the class of solutions of the homogeneous wave equations for which the boundary conditions given by

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Eqs. (1) - (3) are local. It is clear that plane waves belong to this class. The boundary problem for plane waves is solved with the aid of the reflection coefficient and it turns out that it can also be introduced in the more general case. It is clear from the boundary conditions (Eqs. 2-3) that they are local if the electromagnetic field components on $z = 0$ are the eigenfunctions of the two-dimensional Laplace operator Δ. The present discussion is limited to the less general case, where the electromagnetic field components are the eigen functions of the two-dimensional Laplace operator in the entire upper half-space. The solution of the wave equation can then be sought in the form

$$E_i = g_i^{(+)}(x, y)e^{i\varkappa z} + g_i^{(-)}(x, y)e^{-i\varkappa z} \qquad (4)$$

where $g_i^{(\pm)}(x, y)$ satisfy the condition.

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Insert 'Eqs (3) and (4) fm page 65'

$$\Delta g_i^{(\pm)}(x, y) + (k^2 - \varkappa^2) g_i^{(\pm)} = 0 \quad (i = x, y, z) \qquad (5)$$

Vekua (Ref. 2) has shown that the general solution of Eq. (5) can be written down in the form

$$g(x, y) = \alpha J_0(\lambda\rho) + \int_0^{z_+} \Phi_1(t) J_0(\lambda\sqrt{z_-(z_+ - t)})\, dt + \int_0^{z_-} \Phi_2(t) J_0(\lambda\sqrt{z_+(z_- - t)})\, dt. \qquad (6)$$

where α is an arbitrary constant,

$z_{\pm} = x \pm y$,

$\lambda = \sqrt{k^2 - \varkappa^2}$,

$\rho = |z_{\pm}|$.

Φ_1 and Φ_2 are arbitrary holomorphic functions and J_o is the zero-order Bessel function.

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If E_z does not vanish identically, then the solution of the Maxwell equations is of the form

$$E_{x,y} = \frac{i\varkappa}{\varkappa^2 - k^2} \{e^{i\varkappa z} - R(\varkappa) e^{i\varkappa z}\} \frac{\partial g_z}{\partial x, y},$$

$$E_z = (e^{-i\varkappa z} + R(\varkappa) e^{i\varkappa z})\, g_z, \quad R(\varkappa) = \frac{1 - \frac{k}{\varkappa\sqrt{\varepsilon}}\left(1 + \frac{\varkappa^2 - k^2}{k^2\varepsilon}\right)^{1/2}}{1 + \frac{k}{\varkappa\sqrt{\varepsilon}}\left(1 + \frac{\varkappa^2 - k^2}{k^2\varepsilon}\right)^{1/2}}. \quad (7)$$

If, on the other hand, E_z does vanish identically, then

$$E_{x,y} = (e^{-i\varkappa z} + P(\varkappa) e^{i\varkappa z})\, g_{x,y}, \quad P(\varkappa) = \frac{1 - \frac{k}{\varkappa}\sqrt{\varepsilon}\left(1 + \frac{\varkappa^2 - k^2}{k^2\varepsilon}\right)^{1/2}}{1 + \frac{k}{\varkappa}\sqrt{\varepsilon}\left(1 + \frac{\varkappa^2 - k^2}{k^2\varepsilon}\right)^{1/2}}. \quad (8)$$

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Insert Eqs (6), (7) and (8)

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(Author's note: the above boundary conditions can be shown to hold for uneven surfaces and with ε dependent on the coordinates if the following conditions are satisfied

$$\left|\frac{\nabla\varepsilon}{k\varepsilon^{3/2}}\right| \ll 1, \quad R \gg \left|\frac{1}{k\sqrt{\varepsilon}}\right|,$$

where R is the radius of curvature of the surface.)
There are 2 Soviet references.

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ASSOCIATION: Institut radiofiziki i elektroniki AN UkrSSR (Institute of Radiophysics and Electronics of the AS, Ukrainian SSR)

SUBMITTED: April 30, 1960

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CHERNYY, F.B.; BASS, F.G., retsenzent; MISYURE, V.A., retsenzent; MASHAROVA, V.G., red.; SVESHNIKOV, A.A., tekhn. red.

[Propagation of radio waves] Rasprostranenie radiovoln. Moskva, Izd-vo "Sovetskoe radio," 1962. 479 p. (MIRA 15:3)

(Radio waves)

ACCESSION NR: AT4001520 S/3026/62/000/000/0079/0090

AUTHOR: Bass, F. G.

TITLE: On the theory of short- and intermediate- radiowave scattering by sea swells

SOURCE: Radiookeanograficheskiye issledovaniya morskogo volneniya. Kiev, 1962, 79-90

TOPIC TAGS: radiowave scattering, short radiowave scattering, intermediate radiowave scattering, electromagnetic wave scattering, sea swell radiowave scattering, earth curvature effect, scattered radiation statistical property, scattered radiation intensity, scattered spectrum frequency dependence, scattered signal frequency shift, sea depth shift effect, short wave radiomeasurement, intermediate wave radiomeasurement, frequency spectrum analysis, oceanography

ABSTRACT: The components and the frequency shift spectrum of the electromagnetic field scattered by a small sector of the sea surface $z = \zeta(x,y)$ whose surface impedance, $\eta = \varepsilon^{-1/2}$, and form are random stationary functions of time and locally homogeneous functions of coordinates, were determined using perturbation analysis and applying Leontovich boundary conditions.

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$$\left[\vec{n}\ \vec{E}\right] = \eta\left[\vec{n}\left[\vec{n}\ \vec{H}\right]\right], \quad (1)$$

where $\vec{n}$ is a vector normal to the surface of the sea. The effect of earth curvature is considered but the scattering sector is assumed to be flat and large compared to λ and the length of the ocean waves. Also $\frac{2\pi\zeta_{max}}{\lambda} \ll 1$ and $\nabla\zeta \ll 1$. Rectangular coordinates are used within the sector and geographical coordinates outside. The boundary conditions for scattered field components E_{1z} and H_{1z} at surface z = 0 are evaluated from (1) in terms of corresponding incident field components, and Green's integral together with the appropriate Green's function are used to evaluate the scattered field at the point of observation. Maxwell's equations are used to obtain the remaining field components. The final structure of the components is:

$$E_l = A_l(s_0, s_1; z_0, z_1)\,\xi(\vec{q}, t)\,e^{-i\omega t} + A_l'(s_0, s_1; z_0, z_1)\,\psi(\vec{q}, t)\,e^{-i\omega t},$$
$$H_l = B_l(s_0, s_1; z_0, z_1)\,\xi(\vec{q}, t)\,e^{-i\omega t} + B_l'(s_0, s_1; z_0, z_1)\,\psi(\vec{q}, t)\,e^{-i\omega t} \quad (2)$$

where $\xi(\vec{q}, t) = \int e^{i\vec{q}\vec{r}}\,\zeta(\vec{r}, t)\,dS;\ \psi(\vec{q}, t) = \int e^{i\vec{q}\vec{r}}\,\eta(\vec{r}, t)\,dS;\ \vec{q} = \vec{x} - \vec{x}';\ \cos\gamma = \frac{(\vec{x}_1\vec{x}')}{x^2}$

s_0 and s_1 are distances from observation and source to the center of sector, z_0 and z_1 are corresponding elevations, $\vec{q} = \vec{x} - \vec{x}'$, is the difference between the projections of the wave vectors of incident and scattered fields on plane Oxy, and A and B are complex coefficients. Signal form and antenna pattern can be accounted for by inserting a factor $f(\vec{r})$ in the integrand of ξ and ψ. Statistical properties of scattered fields are contained in field correlation tensors

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$$\varepsilon_{ik}(\tau) = \overline{E_i(t)\,E_k^*(t')} = A_i A_k^* \overline{\xi(\vec{q},t)\,\xi^*(\vec{q},t')}\,e^{-i\omega\tau} + $$
$$+ A_i' A_k'^* \overline{\psi(\vec{q},t)\,\psi^*(\vec{q},t')}\,e^{-i\omega\tau},$$
$$H_{ik}(\tau) = \overline{H_i(t) H_k^*(t')} = B_i B_k^* \overline{\xi(\vec{q},t)}\,\overline{\xi^*(\vec{q},t')}\,e^{-i\omega\tau} + \quad (3)$$
$$+ B_i' B_k'^* \overline{\psi(\vec{q},t)\,\psi^*(\vec{q},t')}\,e^{-i\omega\tau},$$
$$D_{ik}(\tau) = \overline{E_i(t)\,H_k^*(t')} = A_i B_k^* \overline{\xi(\vec{q},t)\,\xi^*(\vec{q},t')}\,e^{-i\omega\tau} + $$
$$+ A_i' B_k'^* \overline{\psi(\vec{q},t)\,\psi^*(\vec{q},t')}\,e^{-i\omega\tau}.$$

from which the Umov - Pointing vector components can be evaluated in terms of Dik (0) as

$$S_j = \frac{c}{8\pi}\, Re\, \varepsilon_{jkc} D_{kc}(\vec{q},0), \quad (4)$$

where E_{jkc} is the completely antisymmetric unity tensor of the third rank. The statistical averages $\overline{\xi\xi^*}$ and $\overline{\psi\psi^*}$ of eq. (3) are written as surface integrals of

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the Fourier transforms K_ψ and K_η (with respect to $\vec{\rho} = \vec{r} - \vec{r}'$) of the sea surface autocorrelation functions

$$P_\zeta(\vec{\rho}, \vec{r}, \tau) = \overline{\zeta(\vec{r}, t)\, \zeta(\vec{r}', t')},$$
$$P_\eta(\vec{\rho}, \vec{r}, \tau) = \overline{\eta(\vec{r}, t)\, \eta^*(\vec{r}', t')}, \qquad (5)$$

which in general are also functions of $\vec{\rho}$ so that $\vec{\rho}'$ must be considered as a parameter. For the smooth scattering sector $\overline{\zeta\zeta^*} = SK_\zeta$ and $\overline{\psi\psi^*} = SK_\psi$ and one-dimensional scattering (x - direction) from a rectangular sector is proportional to

$$\left(\frac{\sin\frac{q_y b}{2}}{\frac{q_y b}{2}}\right)^2$$

and has a maximum at $q_y = 0$.

A qualitative interpretation of the frequency shift, Ω, in field scattered by the sea surface was given by Crombie (Nature, 175, 681, 1955) and is not satisfactory. When a general theory developed by Bass (IVUZ SSSR, Radiofizika, IV,58,1961) is applied to the sea surface scattering, using the hydrodynamic and boundary conditions for $\nabla\zeta \ll 1$ given by Landau and Lifshits (Mekhanika Sploshnikh Sred, GTTI, 1954) a differential equation for ζ can be obtained

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$$\frac{d^2\xi}{dt^2} + \Omega^2(\vec{q})\,\xi = 0, \qquad (6)$$

where the frequency shift Λ is

$$\Omega^2(\vec{q}) = \left(g\,q + \frac{\alpha\,q^3}{\mu}\right)\operatorname{th} qh. \qquad (7)$$

and g is the gravity acceleration, α is the capillary constant, h is the depth of the sea and μ is the water density. Equation (7) has a solution

$$\xi(\vec{q},t) = \xi_+(\vec{q})\,e^{-i\Omega(\vec{q})t} + \xi_-(\vec{q})\,e^{i\Omega(\vec{q})t}. \qquad (8)$$

from which it follows that the dependence of tensors $\mathcal{E}_{ik}(\tau)$, $H_{ik}(\tau)$ and $D_{ik}(\tau)$ upon τ is determined by the function:

$$f(\tau) = |\xi_+|^2\,e^{-i\omega_+\tau} + |\xi_-|^2\,e^{i\omega_-\tau}, \qquad (9)$$

$$\omega_\pm = \omega_\pm\,\Omega(q).$$

The spectrum of the scattered signal is the Fourier transform of (τ) and contains 2 spectral lines. For $\alpha = 0$ and transmitter and receiver at the same location,

$$\Omega(q) = \sqrt{\frac{4\pi g}{\lambda}\sin\theta} \quad \text{при} \quad qh \gg 1, \qquad (10)$$

$$\Omega(q) = \frac{4\pi\sqrt{gh}}{\lambda}\sin\theta \quad \text{при} \quad qh \ll 1.$$

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while the corresponding one-dimensional case is

$$\Omega(q) = \sqrt{\frac{4\pi}{\lambda} g \sin\theta \cos\varphi} \quad \text{при} \quad qh \gg 1,$$
$$\Omega(q) = \frac{4\pi \sqrt{qh}}{\lambda} \sin\theta \cos\varphi \quad \text{при} \quad qh \ll 1. \tag{11}$$

Spreading of spectral lines due to finite scattering sector area can be estimated from

$$\Delta\Omega \sim \frac{2\pi}{a} \sqrt{gh} \text{ при } qh \ll 1,$$
$$\Delta\Omega \sim \frac{\pi}{a} \sqrt{g/q} \text{ при } qh \gg 1. \tag{12}$$

where "a" is some chosen dimension of scattering section. "In conclusion, the author expresses his gratitude to S. Ya. Braude, B. D. Zamarayev, A. V. Men' and I. Ye. Ostrovskiy for helpful discussions which were of great assistance during this work". Orig art. has: 37 formulas.

ASSOCIATION: None

SUBMITTED: 00 DATE ACQ: 07Oct63 ENCL: 00

SUB CODE: GE NO REF SOV: 000 OTHER: 000

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L 16842-63 EWT(1)/BDS AFFTC GW

ACCESSION NR: AR3006325 S/0058/63/000/007/H029/H029

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SOURCE: RZh. Fizika, Abs. 7Zh194

AUTHOR: Bass, F. G.; Braude, S. Ya.; Poplavko, Yu. V.

TITLE: Determination of statistical parameters of sea waves from measurements made at short and medium radio waves

CITED SOURCE: Sb. Radiookeanogr. issled morsk. volneniya. Kiyev, AN USSR, 1962, 96-115

TOPIC TAGS: radio wave propagation, sea surface, scattering, short wave , medium wave

TRANSLATION: On the basis of the result of the preceding work (Abstract 7Zh192), calculation formulas are obtained for the scattering of electromagnetic waves by sea waves, making it possible to determine the parameters of the sea waves. The calculated data are

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compared with experimental results obtained at wavelengths from 10 to 240 meters (Abstracts 7Zh199 -- 191). It is shown that in order to find the radii of correlation and the mean square of the height of the sea waves it is necessary to measure the scattered signals at two wavelengths and to find its angular distribution in space. An interpretation is presented for the frequency spectrum of the scattered field and its structure at different distances. Bibliography, 43 titles. F. Bass.

DATE ACQ: 15Aug63 SUB CODE: PH, GE ENCL: 00

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43128
S/181/62/004/011/029/049
B125/B186

26.2351

AUTHORS: Bass, F. G., Kaganov, M. I., and Yakovenko, V. M.

TITLE: Cherenkov radiation and supplementary waves in a dielectric

PERIODICAL: Fizika tverdogo tela, v. 4, no. 11, 1962, 3260-3265

TEXT: The spectral density of the radiation emitted by a particle, moving perpendicularly to the interface dielectric - vacuum (z = 0), is investigated and calculated. Special attention is paid to the generation of supplementary transverse waves of exciton origin. In addition to excitation of exciton waves, their transformation into electromagnetic waves at the interface are considered. The system is described by the Maxwell equations.

$$\mathrm{rot}\,\mathbf{H} = \frac{4\pi}{c} ev\delta(z - vt)\delta(x)\delta(y) + \frac{1}{c}\frac{\partial \mathbf{E}}{\partial t} + \frac{4\pi}{c}\frac{\partial \mathbf{P}}{\partial t}, \quad (1)$$

$$\mathrm{rot}\,\mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{H}}{\partial t}$$

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for the field excited by a particle moving at the velocity v, the equation

$$\frac{\partial^2 \mathbf{P}}{\partial t^2} + \omega_0^2 \mathbf{P} - \alpha_1 \Delta \mathbf{P} - \alpha_2 \,\mathrm{grad\,div}\, \mathbf{P} = \gamma \mathbf{E} \qquad (2)$$

for the polarization P in the dielectric, the common boundary conditions for the continuity of the tangential components, and a linear condition which is very general for isotropic dielectrics, written in the form $\partial \vec{P}/\partial n + \delta \vec{P} = 0$.

The solution can be found in the form $\vec{E} = \int \vec{E}_{\varkappa\omega}(z) e^{i(\varkappa\rho - \omega t)} d\vec{\varkappa} d\omega$. ω_0 is the frequency of exciton absorption; α_1, α_2, and γ are constants describing the structure of the exciton bands. The radiation arising in the vacuum, due to the interaction of the particle with the dielectric, consists of common transition radiation, the Cherenkov radiation, and longitudinal and transverse exciton waves. On leaving the dielectric these two exciton waves become transformed to transverse electromagnetic waves. A continuous Cherenkov radiation spectrum occurs on the boundary of the dielectric plate when particles with sufficiently high speed are leaving this. At decreasing velocities of the particle this spectrum is narrowed, and it disappears completely if the velocity approaches the value c/n_0. At further deceleration a narrow line, associated with the exciton wave, is observed on the entry side. It is shown that the group velocity corresponding to the exciton wave is negative. In isotropic optically active media, (2) is to be replaced by

$$P + g\varepsilon\frac{c}{\omega}\,\mathrm{rot}\,P := \frac{\varepsilon-1}{4\pi}E;\quad g = \frac{f\omega}{c(\omega_0^2-\omega^2)\varepsilon}. \qquad (15)$$

after Fourier transformation with respect to time. ω is the radiation frequency. At $\varepsilon \gg 1$ the dispersion equation has generally three roots. Hence the Cherenkov radiation propagates on the surface of three cones. Fig. 2 shows the frequency dependence of the refractive indices for 2 media, considering all constants of both media as equivalent and assuming that two types of waves propagate in the optically active media: $n_1^2 = \varepsilon$, $n_2^2 = 1/\varepsilon^2 g^2$. Since spatial dispersion occurs in frequency ranges far from

ω_0 the absorption plays only a minor role and the exciton waves can be observed experimentally. There are 2 figures.

ASSOCIATION: Institut radiofiziki i elektroniki AN USSR (Institute of Radio-physics and Electronics AS UkrSSR). Fiziko-tekhnicheskiy institut AN USSR, Khar'kov (Physicotechnical Institute AS UkrSSR, Khar'kov)

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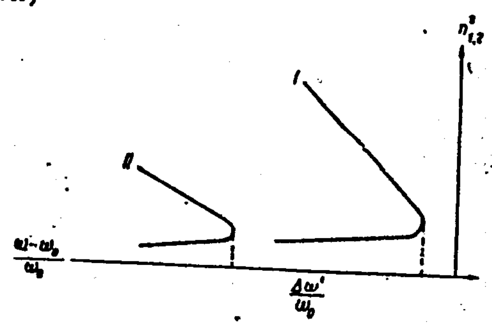
Fig. 2: Frequency dependence of the refractive indices for two media;
Legend: I is an isotropic nongyrotropic medium, II is an isotropic optically active medium.



36969
S/141/62/005/001/019/024
E039/E485

9,3700

AUTHORS: Bass, F.G., Khankina, S.I.

TITLE: The loss of energy by particles moving over an ideal conducting statistically rough surface

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy. Radiofizika, v.5, no.1, 1962, 174-176

TEXT: When particles move over an ideally conducting rough surface there is a loss of energy due to the particles becoming charged, in addition to the usual losses such as Cherenkov radiation and polarization losses. The loss of energy per unit length for particles moving along the x_1 axis is given by

$$\frac{dW}{dx_1} = q\mathcal{E}_1 \qquad (1)$$

In the case of a statistically rough boundary the electromagnetic field can be divided into its average and fluctuating parts, and the statistical irregularity is given by

$$\mathcal{E} = E + \xi \qquad (2)$$

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where E is the average value of the electric field and ξ the fluctuating part. The average loss of energy is then defined by the average electric field

$$\frac{d\bar{W}}{dx_1} = qE_1 \quad (3)$$

where $\bar{W}$ denotes a statistical average.
The average field over a statistically rough surface may be defined by reducing it to the equivalent field over a smooth surface. By assuming that particles with a charge q move with a velocity v in a vacuum along the axis x at a distance a from an ideal conducting medium, the following expression is obtained for the loss of energy from the particles

$$\frac{d\bar{W}}{dx_1} = \int_0^\infty \Phi(\omega)d\omega \quad (7)$$

where $\Phi(\omega)$ is the density loss spectrum for unit frequency interval. A simplified formula for $\Phi(\omega)$ is given.
An additional note is included which extends the calculations to

cover the case of energy loss from dipoles and charged filaments.

ASSOCIATION: Khar'kovskiy institut radiofiziki i elektroniki AN UkrSSR (Khar'kov Institute of Radiophysics and Electronics AS UkrSSR)

SUBMITTED: July 15, 1961

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E032/E314

9,9110

AUTHORS: Bass, F.G., Kaner, E.A. and Pospelov, L.A.

TITLE: Radio-wave fluctuations in the near zone over a plane separation boundary

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, v. 5, no. 2, 1962, 255 - 259

TEXT: The authors investigate fluctuations in the near zone when the source and the receiver are located in a medium with random fluctuations $\delta\varepsilon$ in the dielectric constant. The fluctuations $\delta\varepsilon$ are assumed to be a random process which is stationary in time and uniform in space, so that the average $\overline{\delta\varepsilon(\underline{r}, t)\delta\varepsilon(\underline{r}', t)}$ is a function of the difference $\underline{r} - \underline{r}'$ only. Using the results of previously published papers (Ref. 1 - E.A.Kaner, F.G. Bass - DAN SSSR, 127, 792, 1959; Ref. 2 - Kaner and Bass - Izv.Vyssh. uch. zav. - Radiofizika, 2, 553, 1959; Ref. 3 - -do- 565 and Ref. 4 - Bass, S.Ya.Braude, A.V. Men' and E.A. Kaner - UFN, 23, 89, 1961), formulae are

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Radio-wave fluctuations S/141/62/005/002/007/025
E032/E314

derived for the phase fluctuations and relative amplitude fluctuations in the troposphere above a perfectly-conducting plane separation boundary. The formulae hold in the near zone, where the dimensions of the first Fresnel zone are small compared with the irregularity dimensions. The distribution of the fluctuation components of the field, their phases and amplitudes and the dependence of the r.m.s. fluctuations on frequency, path length, polarization and the position of the transmitter and receiver above the separation boundary are determined. The correlation between phase and amplitude fluctuations is calculated in the transverse direction and the region near the zero average field is investigated. It is shown that the presence of a separation boundary in the case of the near zone leads to a modification of the fluctuation characteristics as compared with an infinite space.

ASSOCIATION: Institut radiofiziki i elektroniki AN UkrSSR (Institute of Radiophysics and Electronics of the AS UkrSSR)

SUBMITTED: September 2, 1961

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E032/E414

AUTHORS: Bass, F.G., Khankina, S.I.

TITLE: Energy losses of a charge moving above an anisotropic medium

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Radiofizika, v.5, no.2, 1962, 408-411

TEXT: The authors are concerned with the motion of a charge moving with a constant velocity in vacuum above an arbitrary anisotropic medium. Maxwell's equations are solved for two types of moving charges, namely a point charge and a charged filament. Explicit formulae are derived for the energy loss per unit path. The discussion is then specialized to the case of a uniaxial crystal when 1) the optic axis is perpendicular to the separation boundary, 2) the optic axis is parallel to the separation boundary and to the direction of motion of the charge and 3) the optic axis is parallel to the separation boundary and perpendicular to the direction of motion of the charge.

VB

ASSOCIATION: Institut radiofiziki i elektroniki AN UkrSSR (Institute of Radiophysics and Electronics AS UkrSSR)

SUBMITTED: November 5, 1961

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9.9300

AUTHOR: Bass, F. G.

TITLE: Influence of regions of inapplicability of geometrical optics on wave scattering by permittivity fluctuations

PERIODICAL: Ukrayins'kyy fizychnyy zhurnal, v. 7, no. 4, 1962, 409-415

TEXT: The effect is considered of reflection points and turning points on an electromagnetic field, scattered by permittivity fluctuations. The intensity of the scattered radiation is calculated. In the references, no formulas for the intensity were obtained in closed form. It is shown that, under certain assumptions, the problem reduces to solving a scalar wave equation. Only inhomogeneities, large in comparison with the wavelength, are considered. It is further assumed that geometrical optics is inapplicable at a single point only. The

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